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Efforts for the second six months of the subject project have continued to focus on determining how expert subjects solve map reading problems. A procedure for collecting and analyzing protocols of expert subjects as they solve problems has been worked out and this is being validated on new subjects. A simulated map reading situation has been developed for laboratory research and this is being exploited to manipulate information available in the map reading situation. Work is also continuing on the characterization of the map readings problem for computational modeling.

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20 June 1989

TO: Air Force Office of Scientific Research

FROM: Herbert L. Pick Jr. & William B. Thompson

SUBJECT: AFOSR-88-0187. "Topographic Map Reading"
Interim 12-month report

Efforts for the second six months of the subject project have continued to focus on determining how expert subjects solve map reading problems. A procedure for collecting and analyzing protocols of expert subjects as they solve problems has been worked out and this is being validated on new subjects. A simulated map reading situation has been developed for laboratory research and this is being exploited to manipulate information available in the map reading situation. Work is also continuing on the characterization of the map reading problem for computational modeling.

For protocol analysis subjects are presented with a localization field problem. This essentially consists of determining, on the basis of perceptual information, the location on a map of a current observation point. Subjects are taken blind folded or with closed eyes to an observation point, given a topographic map, and are asked to determine their position on that map. (This situation is not unlike that faced by a pilot who has strayed off course and then parachuted into relatively unknown territory.) In the present case there is considerable uncertainty, not only as to position but also of the orientation of the map in relation to the viewing direction in the situation. This is because all directional information has been removed from the map so as to force the subjects to rely primarily on the topographic features of the map and environment. Subjects are asked to find their current position on the map describing their mental processes while doing so. They are given preliminary practice in the laboratory in introspecting on their thinking processes on unrelated map reading tasks. To aid later analysis subjects are trained to label on the map features they are referring to while solving the problem. Similarly an experimenter labels on another map the features the subject is referring to in the real environment. Some subjects are also videotaped while performing the task so as to verify where they are pointing both on map and in the world.

Abstractly the localization task is conceived of as the establishment of a correspondence between scene and map. The current working model consists of feature extraction from scene and map and operations to establish a correspondence between the two.

In the analysis the protocols are segmented into propositions. Each proposition is coded as to domain (map, scene, or both), operation (e.g., recognition-extraction, correspondence, etc.). Then the features are identified (e.g. hill, ridge, river valley, etc.), then the properties of the features (e.g. elevation, size, slope, surface features, etc.) and finally relations among features. The identification of features forms the basis of further analysis of which features are identified in each domain, and in what order. How far, wide, and close are the features and to what extent do they correspond in map and scene? What attributes characterize different features and what clusters of features themselves constitute an integral feature? (For example, the convergence of two slopes may form a ridge which is treated as a single feature in itself.) The analysis of operations begins with the identification of features which trigger formation of hypotheses. Of particular interest is the number and level of detail of the hypotheses; to what extent are hypotheses single or multiple, to what extent are they entertained concurrently or serially. How explicit are they? The final aspect of analysis of operations focuses on strategies for hypothesis testing. What kind of evidence is used for testing hypotheses? What evidence is used to decide among competing hypotheses? Are disconfirming data explained away? How are errors detected? What is the procedure for dealing with the consequences of errors detected in previously "verified" hypotheses?

As a first step toward experimental manipulation of the information used in map reading a laboratory simulation of the basic localization task was developed. This simulation consists of two parts: a map task and a scene task. The map task involves asking a subject to identify which of three direction lines from a single point specified on a topographic map corresponds to the particular view of a landscape slide. The scene task in an analogous way involves asking the subject to identify which of three slides of landscapes corresponds to a particular direction of view from a station point specified on a map. (These tasks are considerably easier than the field localization task in as much as there is considerable partial information provided; the correct station point is specified and only the direction of view is at issue.)

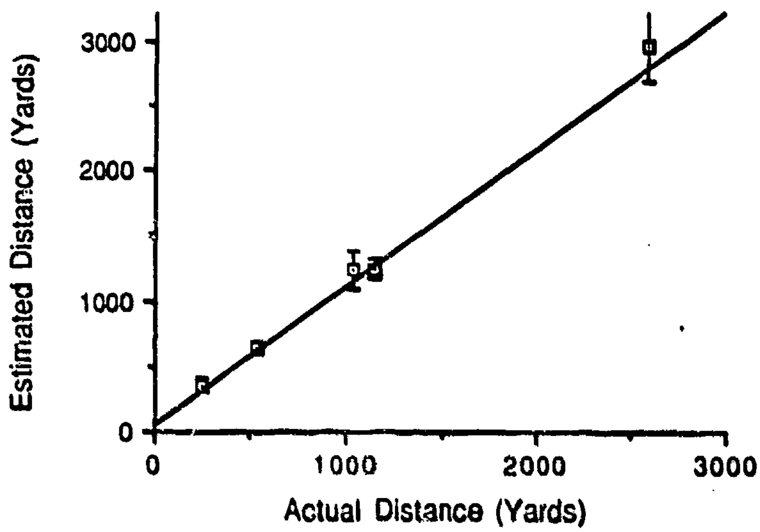
To vary information available in the simulation situation portions of the map were occluded. Different groups of subjects were asked to identify the direction lines or scene when the entire map was available, when the center third of the area around the specified station point was occluded, and when the complementary distal two thirds of the area around the station point was occluded. Thus a condition of full information was compared with a large amount of distal information and with a small amount of proximal information. Subjects performed these tasks with maps and views of five different sites differing considerably in topography, three set in Minnesota, one in Arizona, and one in New Mexico.

In the map task (identifying which of three lines on map corresponds to a particular scene) percent correct judgments for the three information conditions were 59.8, 42.0, and 34.8 respectively for the full map available, center 1/3 masked, and outer 2/3 masked. Chance performance in this task is 33% so the outer 2/3 masking is on the average no better than chance. The ordering of these condition is not too surprising since it corresponds with the order of amount of information available. However, specific sites even in the outer-2/3-masked condition condition can produce better-than-chance performance. Indeed for one of the five sites, performance in this condition was significantly better than that of the inner-1/3-masked condition and no different than the full map condition.

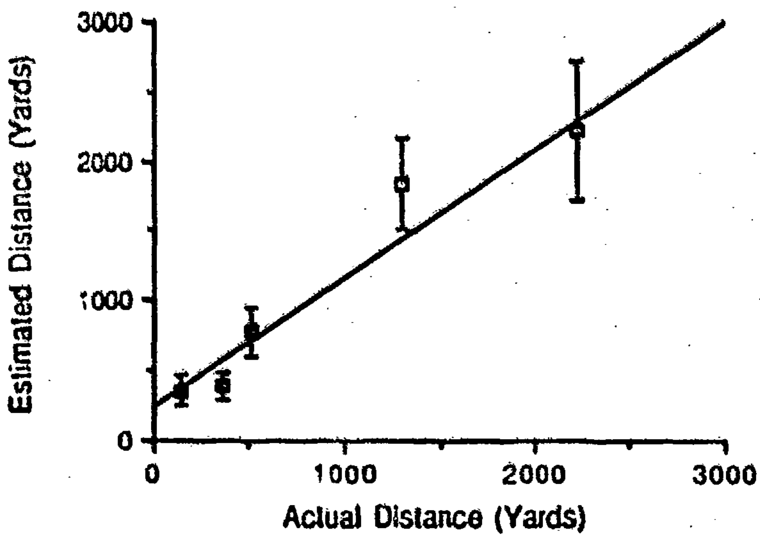
For the scene task (identifying which of three slides of scenes corresponds to a direction line specified on a map) percent correct judgments were respectively 58.6, 49.4 and 56.0 for the full map, inner-1/3-masked, and outer-2/3-masked conditions. Although the full map condition resulted in higher accuracy than the masked conditions these differences were not significant. The asymmetry of results for the map and scene tasks may be due to the fact that in both conditions only the map was masked rather than the scene. In some cases in the scene task specific results are intelligible by reference to the specific features included or occluded in the particular masking conditions. In future work it is planned to use such interpretation to choose particular foils for the incorrect scenes and direction lines in establishing simulation problems.

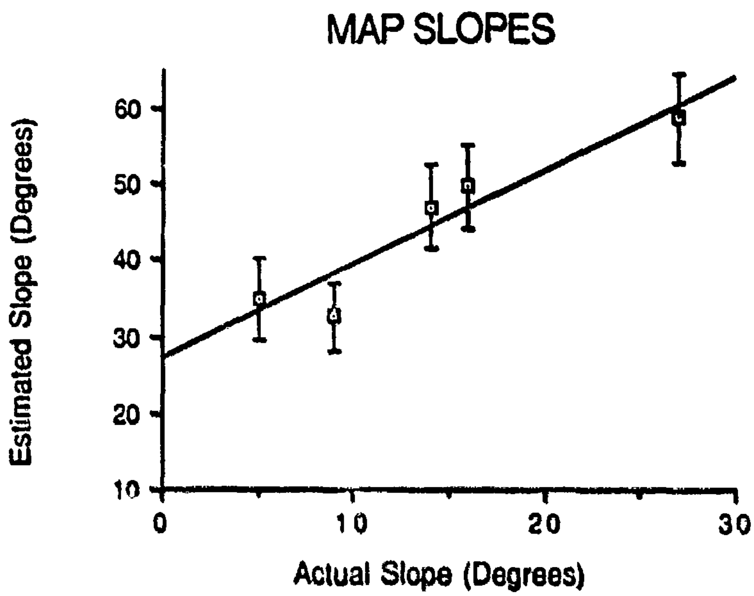
Accuracy of judgment of topographic features may place boundaries on performance in the localization task in the field and/or in the laboratory. To begin to assess what such limitations might be the same subjects who participated in the simulated laboratory localization study were asked to make slope and distance judgments with respect to the laboratory scene and with respect to the map. For the scene subjects were asked to judge the metric distance from the point of observation (camera station point) to specified features on the map. Subjects were also asked to estimate the slopes between pairs of specified points indicated on the slide of the scene. Similarly subjects were asked to estimate distances and slopes between points specified on maps. The attached figures portray the relation between the judged values and the actual distances and slopes for both maps and scenes. The general functions suggest a relatively good relationship between estimated and actual values. However, it should be noted that except for estimations of distances on maps the variability of judgment is quite high. The precision for map distances is not too surprising given that the scale was available on the maps. It is also interesting to note that although the relative relationship for estimation of slope inclination is quite good the absolute values tend to be considerable overestimations and the slope of the functions is considerably greater than 45 degrees (taking into account the different axis scales on the graphs). It is a common observation that we tend to overestimate the steepness of hills in nature but why this should be true for the symbolically represented information on topographic maps is not clear.

MAP DISTANCES



SCENE DISTANCES




MAP SLOPES
Estimated Slope (Degrees)
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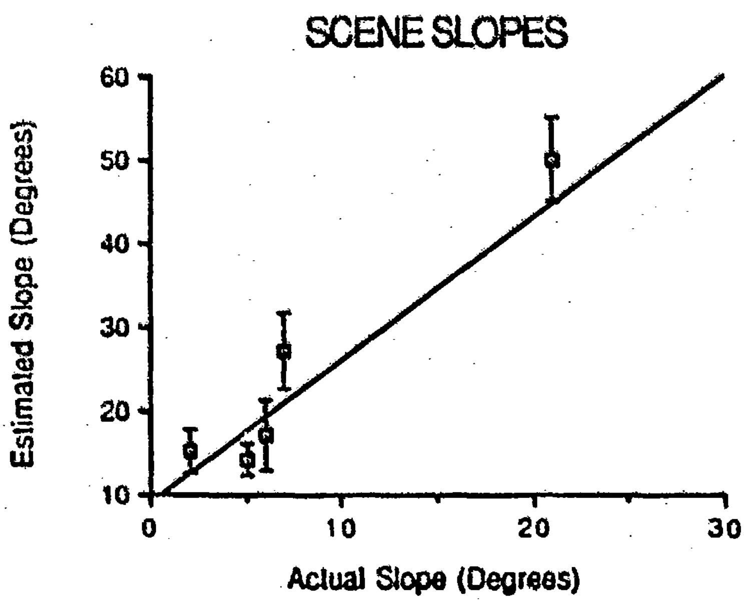
50
40
30
20
10
0
10
20
30
Actual Slope (Degrees)


SCENE SLOPES
Estimated Slope (Degrees)
60
50
40
30
20
10
0
10
20
30
Actual Slope (Degrees)